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Project characteristic-based performance prediction model for school constructions: hierarchical regression approach

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Abstract: Project underperformance remains a significant concern in the construction industry. The majority of prior studies have focused on identifying the subjective factors that affect project performance. However, there are currently no in-depth studies evaluating the influence of project characteristics and managerial/organizational obstacles on construction project performance for design-bid-build projects using empirical data. Therefore, this study aims to present a predictive model that illustrates the correlation between project characteristics, managerial/organizational complexity and difficulties, and construction project performance. Project data relating to the construction of 101 public schools within a developing country was collected. Subsequently, the project characteristics were identified, and two performance indicators (schedule performance index and cost performance index) were calculated for each project. A survey was conducted with construction professionals who took part in all of the control and management processes of these school projects to evaluate their managerial and organizational difficulties. Hierarchical regression model approach and correlation analyses were employed to develop the predictor model. The results indicate that factors such as location, school type, and project duration significantly predict both the schedule performance and managerial and organizational difficulties in school construction. An indirect correlation, rather than a direct association, was found between schedule performance and managerial and organizational difficulties. The proposed model will be a helpful guide for construction professionals, engineering managers and government decision-makers seeking to improve the performance of "design-bid-build" school construction projects. We suggest integrating the qualification-based selection (QBS) system into traditional procurement methods for public investments.

Keywords: Project performance, design-bid-build contract, school construction, hierarchical regression model.

1. Introduction

The construction industry faces issues of poor project performance and low productivity due to the complexity and dynamicity of construction projects. McKinsey Global Institute's report suggests that both developing and developed countries encounter similar problems during the life cycle of construction projects (McKinsey Global Institute, 2017). Unlike many other sectors, such as manufacturing and agriculture, which are seeing productivity growth averaging 3.8% per year, the construction industry is struggling to surpass the desired level of efficiency, with a productivity growth rate of only 1% per year (McKinsey Global Institute, 2017). What's more, the global construction industry is becoming more competitive every year. This is driving contractors to improve efficiency and productivity. Nevertheless, the construction industry's financial importance and contribution cannot be ignored. For instance, construction projects typically account for 9% to 15% of the GDP in developing countries (Hampson et al., 2014). As a result, there has been increased emphasis on measuring and monitoring the performance of both construction firms and projects in recent years. Consequently, professionals, engineering managers and academics have placed significant emphasis on dependable performance indicators to enhance project monitoring and control practices (Chan and Chan, 2009; Moradi et al., 2022; Su and Khallaf, 2022). While there are numerous underlying success criteria for construction projects, the predominant factors used to evaluate success are time, cost and quality, collectively referred to as the "Iron Triangle" in construction (Ma and Fu, 2020; Marzouk and Gaid, 2018; Su and Khallaf, 2022). Safety (Mellado et al., 2020). In addition, working environment (Chan et al., 2004; Orihuela et al., 2017) are also highlighted as essential project performance measures. Despite criticisms of time delays and cost overruns as inadequate performance indicators because of their limitations in assessing overall project performance (Leon et al., 2018; Meng, 2012), it is noteworthy that they are still more reliable and easily monitored than other performance measures during construction processes (Orihuela et al., 2017; Radujković et al., 2010; Su and Khallaf, 2022).

A number of studies have attempted to identify the underlying reasons for cost overruns and delays in construction projects. Notable works on the subject include those by Alshihri et al. (2022), Amoatey et al. (2015), Chan et al. (2004), Durdyev (2020), Kavuma et al. (2019), Mpofu et al. (2017) and Yehiel (2013). The majority of these works employ qualitative methodologies and conduct surveys among construction professionals to investigate the underlying factors that impact project time and cost performance. This is evident in the works of Amoatey et al. (2015), Egwim et al. (2021), Gunduz and Tehemar (2020), Johnson and Babu (2020), Kavuma et al. (2019), Mpofu et al. (2017) and Yehiel (2013). However, only a few studies have actually analyzed the variances in actual project time and cost in order to evaluate which attributes have a significant impact on construction project performance (Kaming et al., 1997). Moreover, while it is widely recognized that construction project characteristics such as project type, location, and size (Cho et al., 2009) and bidding methods (Chan et al., 2004; Minchin et al., 2013; Yu et al., 2017) have a significant impact on project performance, there is a lack of comprehensive studies that attempt to explore the empirical correlation between these attributes and project performance.

Furthermore, project managerial complexity or difficulty could significantly impact construction project performance either positively or negatively, as noted by Ma and Fu (2020). The effects of project characteristics and managerial complexity on project performance in construction are still unclear. Therefore, the primary purpose of this study is to present a new predictive model that quantitatively demonstrates the direct and indirect relationships between project characteristics, managerial and organizational complexity or difficulty, and construction project performance, utilizing real-time variances in both cost and time. In other words, the research question is that what are the main indicators for poor project performance in school constructions. Having a clear understanding of these significant predictors and their interrelationships will greatly aid construction practitioners and engineers in implementing more dependable project management practices, and as a result, effectively improve construction project time and cost performance.

2. Background

2.1. *Project performance indicators in construction*

Key performance indicators (KPIs) are a key measure of project success in a variety of industries, as well as in the construction industry. Despite the importance of performance indicators in evaluating project success, there is no consensus on which indicators to use, especially in construction due to the unique characteristics of construction projects. Two different approaches, Performance Measurement Systems (PMS) and key performance indicators (KPIs), have been adopted in literature to define project performance indicators systematically (Haponava and Al-Jibouri, 2012). KPIs are used to measure the partial or final performance of a project, while PMS is used to quantify the performance of an organization (Franceschini et al., 2009). KPIs are widely used in construction projects to provide benchmarking at the company and project level (Yuan et al., 2009). Baccarini (1999) proposed an alternative classification for project success criteria, which comprised two components: product success factors and project success factors. According to Baccarini (1999), project management success is associated with process achievements, whereas product success is centered on the final product or deliverable. Skibniewski and Ghosh (2009) proposed the KPIs approach, which classifies indicators into two categories: project performance indicators (e.g. cost, time, client satisfaction, and predictability) and company performance indicators (e.g. safety, profitability, and productivity). Project performance indicators can be classified into two categories: quantitative and qualitative. Quantitative approaches to project performance indicators are measurable, objective, and reliable, whereas qualitative ones are more subjective and difficult to measure and evaluate (Chan and Chan, 2004).

Although time, cost, and quality are considered as traditional performance indicators (Leon et al., 2018; Meng, 2012), it is widely accepted that they are more reliable, objective, and measurable compared to other qualitative and quantitative indicators (Orihuela et al., 2017; Radujković et al., 2010; Su and Khallaf, 2022). Several studies highlighted that the achievement of time, cost, and quality requirements, referred to as the "Iron Triangle" in construction projects, heavily determines project failure or success (Chileshe and Berko, 2010; Haponava and Al-Jibouri, 2012; Mulla and Waghmare, 2015). Previous review studies considered cost, time, and quality as the top-ranked performance indicators (Moradi et al., 2022; Su and Khallaf, 2022). Construction project practitioners and technical managers often consider and evaluate the performance of construction projects using these objective performance indicators (Mellado et al., 2020). The "iron triangle" is also acknowledged as one of the most crucial parameters to meet client satisfaction (Tripathi and Jha, 2018).

In addition to these performance indicators, a previous study concluded that the tendering method or contract type also significantly influences construction project performance (Chan et al., 2004). In the construction industry, alongside the traditional or design-bid-build project delivery method, there are various contract types including design-build, built-operate-transfer, and management contracting (Montalbán-Domingo et al., 2019). Several studies have attempted to compare the performance of projects delivered through different methods, particularly based on time and cost parameters (Abou Chakra and Ashi, 2019; Hashem M. Mehany et al., 2018; Minchin et al., 2013; Shrestha and Fernane, 2017; Yu et al., 2017). Previous studies have shown that projects delivered using the design-build method have significantly better time and cost performance than design-bid-build projects (Minchin et al., 2013; Shrestha and Fernane, 2017). However, the performance of projects tendered via different procurement methods varies depending on the characteristics of construction projects, and no consistent results have been achieved regarding their performance (Abou Chakra and Ashi, 2019; Moon et al., 2020). However, the "traditional" contract type is commonly associated with poor time and cost performance compared to other delivery methods (Minchin et al., 2013; Nguyen et al., 2018).

2.2. *Earned value management (EVM) approach*

In construction and diverse industries, various project management approaches such as agile, lean, waterfall, scrum, and critical path project management are utilized for controlling and monitoring project performances (Wells, 2012). Earned Value Management (EVM), which is strongly suggested by Project Management Institute (PMI, 2005), has gained great attraction among industry practitioners and engineers globally (Kerzner, 2014). According to PMI (2005), EVM is an effective and beneficial empirical method for evaluating and monitoring the overall progress of a project from beginning to end. Various studies (Batselier and Vanhoucke, 2015; Proaño-Narváez et al., 2022; Zahoor et al., 2022) have significantly demonstrated the efficiency of EVM in providing insight into project cost and time performance. With EVM, managers and engineers can check whether a project is behind or ahead at any time in terms of cost and time according to planned ones. The EVM method is widely recognized as a practical tool in construction management due to its easy and trackable comparisons of time and cost based on the plan (Czemplik, 2014).

The EVM technique utilizes two performance metrics - the schedule performance index (SPI) and cost performance index (CPI) - for measuring time and cost, which are widely used in construction. To calculate the SPI, one uses the earned value (EV) and planned value (PV) coefficients (SPI=EV/PV). The term EV refers to the budgeted cost or 'worth' of completed work at any given time, while PV is the baseline of time or cost. Furthermore, the CPI is calculated by dividing the EV by the actual cost (CPI=EV/AC). The term 'actual cost' represents the total amount spent on the project up until a given point in time. A CPI (Cost Performance Index) or SPI (Schedule Performance Index) value below 1.00 indicates that the project is behind schedule or over budget, indicating poor performance (PMI, 2005). As noted by Proaño-Narváez et al. (2022), the EVM (Earned Value Management) method utilizes two performance indicators, cost and time, to provide accurate monitoring and evaluation of project progress. In addition to project progress monitoring, the EVM (earned value management) approach can also predict the final cost and time required based on the data collected from previous projects (Barrientos-Orellana et al., 2022; Kim and Reinschmidt, 2010; Zahoor et al., 2022). As highlighted by Proaño-Narváez et al. (2022), this quantitative approach has significant potential to enhance cost and time performances during the construction process, enabling managers to implement appropriate strategies.

2.3. *Knowledge gap and research aims*

Several studies have been conducted in construction to understand the critical factors that impact project performance. These attempts have contributed significantly to the body of knowledge. Despite these studies, some points remain uncertain. First, the studies mostly used a qualitative approach and surveyed construction experts to identify key performance indicators (KPIs) (Amoatey et al. 2015; Egwim et al. 2021; Gunduz and Tehemar 2020; Johnson and Babu 2020; Mpofu et al. 2017; Yehiel 2013). However, only a few studies analyzed real project time and cost data to explore crucial project performance indicators (Kaming et al. 1997). Most KPIs are developed for general construction projects rather than specific ones (Heravi and Ilbeigi, 2012; Kavuma et al., 2019; Nassar and AbouRizk, 2014; Xiao and Proverbs, 2003). Additionally, it is well-known that the "Design-Bid-Build" delivery method is widely used, particularly in developing countries within public investment projects, and has a negative impact on construction project performance (Calahorra-Jimenez et al., 2020; Minchin et al., 2013; Nguyen et al., 2018). However, there have been no studies conducted to examine the underlying factors that cause project performance for this particular contract type in construction. Moreover, the complexity of managerial and organizational structures is emphasized to be another important attribute that affects the performance of construction projects (Ma and Fu, 2020). However, this point has yet to be evaluated in detail using empirical time and cost performance indicators. Despite exploring the effect of project characteristics on performance through a questionnaire conducted with construction professionals (Cho et al., 2009), no studies have yet evaluated this point using empirical project time and cost data in conjunction with these parameters. The unique characteristics of construction projects make it challenging to extract reliable main predictors that significantly impact project performance. Forecasting project performance through a selection of reliable and specific attributes is vital. Nevertheless, there is still a shortage of crucial predictors for construction project performance based on project characteristics.

Therefore, the primary objective of this study is to bridge the gap by introducing a predictor model for special construction projects delivered through the "design-bid-build" procurement method, using real and empirical performance indicators. The purpose of this study is to examine the relationships among project characteristics, managerial and organizational complexity/difficulty, and SPI and CPI in the proposed model.

3. Research methodology

A conceptual model was initially developed to establish a predictor model and demonstrate all connections between project characteristics, managerial, and organizational complexity/difficulty with project performance. Next, by collecting data on real and completed projects, a project database was established. The EVM approach was used to attain empirical indicators for project performance. At the same time, a survey was conducted with construction experts, who participated in the management of all these projects, on managerial and organizational complexity/difficulty. The collected data from the projects and survey were converted into a more structured format prior to analysis. By performing hierarchical regression model and correlation analyses, our objective was to present a final predictor model that demonstrates important relationships between project characteristics, managerial and organizational complexity/difficulty, and two distinct project performance metrics (Fig. 1).

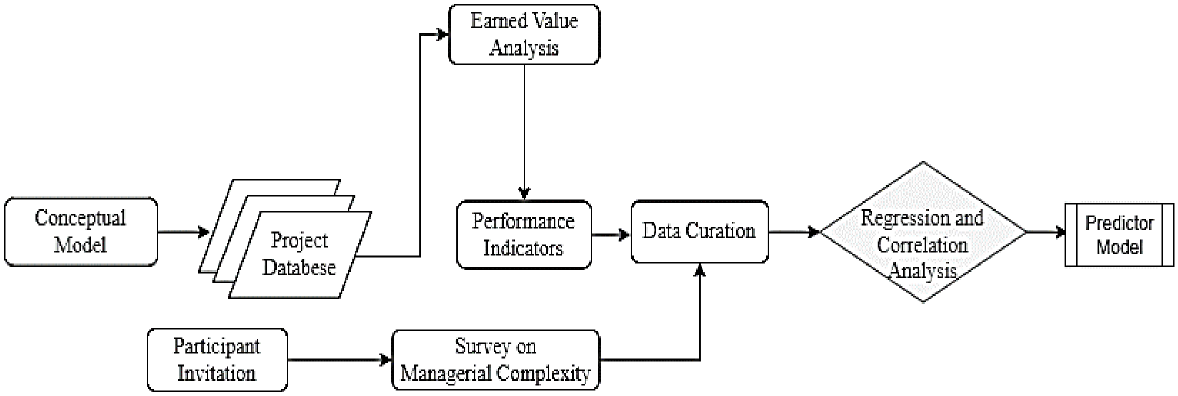

Figure 1. Research methodology flow.

3.1. *Conceptual model*

Construction professionals and engineers need a more comprehensible way to visualize and evaluate critical project performance factors. A conceptual framework should reflect all the necessary aspects, including the relationships between project characteristics, managerial and organizational complexity, and project performance. To this end, we have developed a conceptual model (Fig. 2) that demonstrates all related predictors for construction project performance. Regarding project characteristics, several variables such as location (e.g., rural and urban), school type (e.g., high, secondary, primary, and preschool), the number of school classes designed, year of school construction, total construction area, project duration, and unit cost (calculated by dividing total cost to total construction area) were taken into account. These are the primary indicators for project performance in construction, which is reason for selection of these attributes. To measure the managerial and organizational complexity of school projects, we surveyed construction experts working for the Ministry of Education and monitored all construction processes of these school projects to ensure compliance with quality, time, cost, and other contractual requirements on behalf of this government institute. The schedule performance index (SPI) and cost performance index (CPI) were used as the most reliable and accessible project performance indicators.

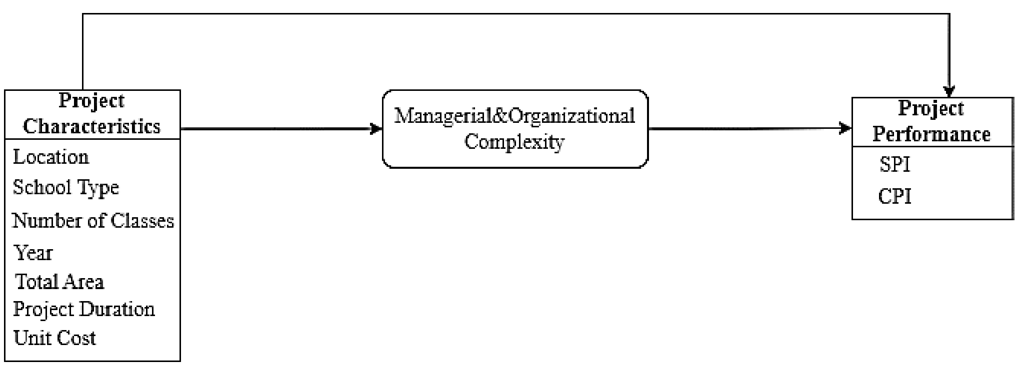

Figure 2. Conceptual framework.

3.2. *Data collection and regression analysis*

Following the development of a conceptual model, we collected data related to 101 school construction projects in Turkey. The data used in the study was taken from the construction works department of the Ministry of Education. These projects were tendered through the “design-bid-build” contract type by the Ministry of Education of a developing country. In addition to project characteristics, we gathered information on planned and final costs and time for each school construction project. This data was used to calculate the SPI and CPI variables. Eleven construction experts were asked four different questions, related to the managerial and organizational complexity of each school project. Managerial and organizational complexity means that the difficulties encountered by the construction professionals during the related projects. The questions asked for a 5-Likert Scale form response (1 = very low, 5 = very high). The topics covered in these questions include the quality of contractor organization, quality deficiencies, client satisfaction, as well as organizational and managerial difficulties observed during school projects (Table 1). The construction experts were only responsible for filling out survey questions for the school projects they had been assigned to. The database on the managerial and organizational difficulties of each school has been completed. Regarding the project characteristics, some parameters such as location, school type, and year of construction were coded in categorical form. However, the remaining project attributes, such as the number of classes, project duration, unit cost, and total construction area, were used in continuous form. To calculate the managerial and organizational complexity or difficulty score of each school project, the means of four ranked questions, as determined by the participants, were considered. As a result, only one continuous variable was included as the managerial and organizational complexity of each school project in the final database.

Table 1. Construction professional information.

Participant	Title	Position	Education level	Experience (year)
1	Civil Engineer	Control Engineer	M.Sc.	11
2	Mechanical Engineer	Control Engineer	M.Sc.	10
3	Mechanical Engineer	Control Chief	B.Sc.	15
4	Mechanical Engineer	Control Chief	B.Sc.	17
5	Architect	Project Coordinator	B.Sc.	22
6	Architect	Project Chief	M.Sc.	24
7	Civil Engineer	Control Engineer	B.Sc.	8
8	Architect	Control Chief	B.Sc.	16
9	Electrical Engineer	Control Engineer	M.Sc.	6
10	Civil Engineer	Control Chief Manager	B.Sc.	8
11	Survey Engineer	Control Engineer	B.Sc.	12

*B.Sc.= Bachelor of Science; *M.Sc. = Master of Science

We employed hierarchical regression model and Pearson's correlation analysis to examine the direct and indirect relationships between project characteristics, managerial and organizational complexity, and project performance. Correlation analysis provides empirical information about direct relationships between each attribute without any control variable, while regression analysis can be used to observe direct and indirect associations from a broad perspective with control variables (Reddy, 2019). In other words, by adopting a hierarchical regression model, we can interpret to which degree the new independent variable influences the dependent variable under some control variables.

The primary reason for selecting the hierarchical regression model approach is that such a mathematical model provides an opportunity for us to evaluate the power and interaction effects of predictors separately on the dependent variable (Radmacher and Martin, 2001). The hierarchical regression model is constructed by step-by-step adding a new set of independent variables (one or more than one) to the initial model, based on the hypothesized order. Independent variables from the previous model become control variables in the new structured regression model. This allows observing the effect of newly added predictor variables on the dependent variable, while controlling for other variables step by step. It facilitates evaluating the indirect effect of one independent variable (e.g., managerial and organizational complexity) on dependent variables (e.g., performance indicators) via another independent variable (e.g., project characteristics). This approach has been implemented successfully for various purposes in the literature (Bringula et al., 2018; Haynes and Love, 2004; Leung et al., 2017). Furthermore, as both categorical and continuous independent variables and continuous dependent variables are present, the hierarchical regression model meets the requirements of the generated dataset for conducting the related analysis in the current study (Leung et al., 2017).

4. Results

Table 2 presents the descriptive statistics of the collected school construction projects. The results show that most projects have poor performance, with mean values of SPI and CPI below 1.00, based on diverse project characteristics. Only schools constructed in rural areas showed slightly better schedule performance. Meanwhile, the unit costs of construction projects range from $42.95 to $64.94 TL. Moreover, school construction exhibits a wide range of total construction area and duration of projects.

Table 2. Descriptive statistics of school construction projects.

		Mean				
		Project duration	Total meter square	Unit cost (TL)	SPI	CPI
Location	Rural (n= 35)	271.05	1259.29	1,897.23	1.003	0.978
	Urban (n=66)	376.56	3678.45	2,143.12	0.925	0.985
School type	High (n=22)	454.76	6238.61	1,789.23	0.883	0.987
	Middle (n=21)	379.28	2916.38	2105.29	0.929	0.994
	Primary (n=41)	312.31	2323.35	1959.03	0.981	0.978
	Kindergarten (n=17)	265.55	1198.55	2979.71	0.917	0.987
Number of classes	24 (n=17)	479.67	7629.43	1307.92	0.898	0.995
	16 (n=21)	355.56	3161.87	1,746.63	0.990	0.984
	12 (n=16)	406.12	2706.34	2,537.09	0.873	0.978
	8 (n=21)	312.64	1952.83	2,647.40	0.961	0.979
	less than 5 (n=26)	252.57	765.25	1,980.16	0.999	0.987
Year	2015- 2017 (n=42)	332.56	3452.51	1,287.23	0.976	0.980
	2017-2020 (n=25)	293.38	2314.48	1,880.27	0.972	1.006
	2020-2022 (n=34)	404.16	2252.93	2685.24	0.887	0.963

Note: TL =Turkish lira.

Pearson's correlation analysis was conducted to evaluate the strength and direction of association between every two factors independently (Table 3). Control variables were not considered. The findings show that the location of school construction projects has an influence on schedule performance ($\rho = -0.332$, $p = 0.01$) and is highly correlated with project duration ($\rho = 0.368$, $p = 0.01$). As expected, a significant correlation was found between project duration and SPI ($\rho = -0.477$, $p = 0.01$), and between project duration and managerial and organizational complexity ($\rho = 0.420$, $p = 0.01$). Several project characteristics such as location, school type, number of classes, and total construction area have a significant impact on the SPI and managerial and organizational difficulties. Furthermore, a strong and negative correlation was observed between CPI and the unit cost of projects ($\rho = -0.323$, $p = 0.01$). In regression models, a negative correlation or prediction coefficient indicates that an increase in the unit cost or project duration results in a decrease in the cost and time performance.

Table 3. Correlation analysis result.

Factors	Loca-tion	School types	Classes	Year	Total area	Project duration	Unit cost	Managerial complexity	CPI	SPI
Location	1	-0.049	0.567**	0.182	0.406**	0.368**	0.096	0.337**	0.009	-0.332**
School types	-	1	-0.418**	0.098	-0.449**	-0.399**	0.144	-0.323**	-0.040	0.214*
Classes	-	-	1	-0.202*	0.740**	0.511**	-0.244*	0.572**	-0.024	-0.254*
Year	-	-	-	1	-0.213*	0.141	0.806**	-0.141	-0.052	-0.259**
Total area	-	-	-	-	1	0.502**	-0.240*	0.404**	-0.008	-0.305**
Project duration	-	-	-	-	-	1	0.142	0.420**	-0.187	-0.477**
Unit cost	-	-	-	-	-	-	1	-0.058	-0.323**	-0.082
Managerial Complexity	-	-	-	-	-	-	-	1	-0.064	-0.1
CPI	-	-	-	-	-	-	-	-	1	0.026
SPI	-	-	-	-	-	-	-	-	-	1

*Correlation significant at the 0.05 level (two-tailed).
**Correlation significant at the 0.01 level (two-tailed).

The reliability of the collected dataset was assessed by conducting a multicollinearity test prior to performing hierarchical regression analysis. The outcome of the multicollinearity test evaluates if the collected data is internally independent of each other, a fundamental requirement of the hierarchical regression analysis (Vatcheva and Lee, 2016). For this purpose, the Variance Inflation Factor (VIF) of each attribute should be less than 5. It indicates that the dataset is reliable and does not have multicollinearity (Akinwande et al., 2015). The multicollinearity test results in this study indicate that almost all calculated VIF values are less than 3, and the remaining values lie between 3 and 5, which indicates that the dataset is reliable and free of multicollinearity. These results are presented in the regression model result tables (Table 4-8).

The hierarchical regression analysis carried out on project characteristics and SPI revealed that the first (F (1,99) = 12.148, p = 0.001, R^2 = 0.11) and second (F (2, 98) = 8.528, p < 0.001, R^2 = 0.15) models were significant predictors for project time performance (Table 4). When other project characteristics, such as project duration and unit cost, are added to the existing blocks, they significantly improve the prediction of schedule performance for school constructions in Model 1f (F (6,94) = 6.771, p < 0.001, R^2 = 0.304) and Model 1g (F (7,93) = 7.047, p < 0.001, R^2 = 0.349). For instance, Model 1g encompassing all project characteristics explains 34.9% of the variance in the schedule performance of school constructions. The project location (ΔR^2 = 0.11, p = 0.001) and duration (ΔR^2 = 0.07, p = 0.003) are the project characteristics that result in the most significant decrease in predictive power for schedule performance. In contrast, the total area (ΔR^2 = 0.029, p = 0.061) has no discernible effect on the prediction power of models for schedule performance.

The results of the hierarchical regression analysis for project characteristics and CPI show that only model 2g (F (7,93) = 4.577, p < 0.001, R^2 = 0.272), which includes all project characteristics, is a significant predictor of cost performance (Table 5). This significant predictive power comes from adding the cost unit factor (ΔR^2 = 0.193, p < 0.001) to the existing block model 2f, which negatively predicts the cost performance of projects. All project characteristics in Model 2g explain 27.2% of the variance in the cost performance of school projects. In addition, although project duration has significant predictive power for cost performance (ΔR^2 = 0.057, p = 0.019), this characteristic does not change the significant impact of Model 2f in predicting cost performance (F (6,94) = 4.577, p = 0.382, R^2 = 0.065). Other project characteristics such as location (ΔR^2 < 0.001, p = 0.929), school type (ΔR^2 = 0.002, p = 0.694), number of classes (ΔR^2 < 0.001, p = 0.967), year (ΔR^2 = 0.003, p = 0.605), and total area (ΔR^2 = 0. 002, p = 0.982) are not significant predictors of cost performance as they have a smaller percentage of variance explaining cost performance and result in a smaller R^2 change for existing models.

The results of the regression models for project characteristics and managerial and organizational complexity/difficulty show that the project characteristics that are location, school type, and number of classes in the first three models; Model 3a (F(1,99) = 12.556, p = 0. 001, R^2 = 0.114), Model 3b (F (2,98) = 12.709, p < 0.001, R^2 = 0.208), and Model 3c (F (3,97) =

16.322, $p < 0.001$, $R^2 = 0.338$) are the main predictors of the managerial and organizational complexity of school projects, explaining 33.8% of the variance (Table 6). Although Model 3d, Model 3e, and Model 3g have a significant impact on predicting managerial and organizational complexity, the project characteristics included in these models, such as year ($\Delta R^2 = 0.002$, $p = 0.609$), total area ($\Delta R^2 = 0.003$, $p = 0.484$), and unit cost ($\Delta R^2 = 0.024$, $p = 0.063$), are not decisive predictors of managerial and organizational difficulties of school construction projects. Overall, all project characteristics in Model 1g, Model 2g, and Model 3g explain 34.9%, 27.2%, and 39.1% of the variances for schedule performance, cost performance, and managerial and organizational difficulties, respectively.

The results of hierarchical regression analysis for project characteristics, complexity/difficulty, and SPI show that while all project characteristics included in Model 4a/1g together are significant in predicting schedule performance ($F(7,93) = 7.047$, $p < 0.001$, $R^2 = 0.349$), the addition of a new variable managerial and organizational complexity/difficulty (Model 4b) does not make a significant contribution to the existing Model 4a/1g in predicting schedule performance (Table 7). The reason for the poor contribution is that the managerial and organizational complexity/difficulty attribute provides a small R2 change in Model 4b ($\Delta R^2 = 0.005$, $p = 0.400$). A similar result was obtained in the regression model for project characteristics (Model 5b, managerial and organizational complexity/difficulty and cost performance), as the managerial complexity factor is not a significant predictor of cost performance (Table 8). The addition of the managerial and organizational difficulty factor to the existing Model 5a provides little R2 change in the prediction of cost performance ($\Delta R^2 = 0.001$, $p = 0.789$).

Table 4. Regression model for project characteristics and schedule performance index.

Model	Project characteristics	B	SE	β	Sig.	VIF	R	R^2	ΔR^2	ANOVA F	ANOVA Sig.
1a	Constant	1.086	0.037	-	0.000		0.332	0.110	0.110	12.148	0.001*
	Location	-0.074	0.021	-0.332	0.001*	1.000					
1b	Constant	1.015	0.049	-	0.000		0.387	0.150	0.039	8.528	0.000*
	Location	-0.072	0.021	-0.322	0.001	1.002					
	School type	0.026	0.012	0.198	0.037*	1.002					
1c	Constant	1.013	0.051	-	0.000		0.387	0.150	0.000	5.638	0.001*
	Location	-0.075	0.026	-0.335	0.006	1.573					
	School type	0.027	0.014	0.207	0.056	1.293					
	Number of classes	0.000	0.002	0.022	0.863	1.900					
1d	Constant	31.241	11.750	-	0.009		0.453	0.205	0.055	6.131	0.000*
	Location	-0.048	0.028	0.195	0.085	1.830					
	School type	0.024	0.013	0.198	0.081	1.302					
	Number of classes	-0.002	0.002	-0.101	0.432	2.204					
	Year	-0.015	0.006	-0.313	0.012*	1.213					
1e	Constant	33.843	11.674	-	0.005		0.484	0.234	0.029	5.755	0.000*
	Location	-0.044	0.027	-0.198	0.110	1.841					
	School type	0.018	0.014	0.136	0.202	1.381					
	Number of classes	0.001	0.002	0.053	0.739	3.082					
	Year	-0.016	0.006	-0.281	0.006	1.230					
	Total area	-0.001	0.000	-0.263	0.061	2.368					
1f	Constant	23.838	11.661	-	0.044		0.551	0.304	0.070	6.771	0.000*
	Location	-0.039	0.026	-0.176	0.138	1.848					
	School type	0.009	0.013	0.068	0.515	1.448					
	Number of classes	0.002	0.002	0.141	0.366	3.192					
	Year	-0.011	0.006	-0.195	0.054	1.338					
	Total area	-0.001	0.000	-0.178	0.194	2.472					
	Project duration	-0.001	0.000	-0.340	0.003*	1.658					
1g	Constant	56.351	17.169	-	0.001		0.591	0.349	0.045	7.047	0.000*
	Location	-0.038	0.026	-0.168	0.144	1.849					
	School type	0.006	0.013	0.043	0.670	1.461					
	Number of classes	0.003	0.002	0.174	0.253	3.217					
	Year	-0.027	0.009	-0.474	0.002	3.069					
	Total area	-0.001	0.000	-0.162	0.223	2.477					
	Project duration	0.000	0.000	0.390	0.001	1.713					
	Unit cost	0.001	0.000	0.369	0.013*	3.022					

*The related new factor added to the model has a significant impact on the dependent variable
Note: Sig. = Significance; ΔR^2 = R^2 change; B = unstandardized coefficient; β= beta coefficient F = F-test value; SE = standard error; VIF = variance inflation factor.

Table 5. Regression model for project characteristics and cost performance index.

Model	Project characteristics	B	SE	β	Sig.	VIF	R	R^2	ΔR^2	ANOVA F	ANOVA Sig.
2a	Constant	0.986	0.025	-	0.000		0.009	0.000	0.000	0.008	0.929
	Location	0.001	0.015	0.009	0.929	1.000					
2b	Constant	0.995	0.035	-	0.000		0.041	0.002	0.002	0.082	0.921
	Location	0.001	0.015	0.007	0.945	1.002					
	School type	-0.003	0.009	-0.040	0.694	1.002					
2c	Constant	0.995	0.036	-	0.000		0.041	0.002	0.000	0.055	0.983
	Location	0.001	0.019	0.004	0.976	1.573					
	School type	-0.003	0.010	-0.038	0.745	1.293					
	Number of classes	0.000	0.001	0.006	0.967	1.900					
2d	Constant	5.440	8.570	-	0.527		0.067	0.005	0.003	0.108	0.979
	Location	0.004	0.020	0.031	0.825	1.830					
	School type	-0.004	0.010	-0.043	0.714	1.302					
	Number of classes	0.000	0.002	0.023	0.878	2.204					
	Year	-0.002	0.004	-0.058	0.605	1.213					
2e	Constant	5.977	8.663	-	0.492		0.086	0.007	0.002	0.141	0.982
	Location	0.005	0.020	0.036	0.795	1.841					
	School type	-0.005	0.010	-0.058	0.631	1.381					
	Number of classes	0.000	0.002	0.027	0.880	3.082					
	Year	-0.002	0.004	-0.066	0.567	1.230					
	Total area	-0.001	0.000	-0.083	0.600	2.368					
2f	Constant	0.053	8.809	-	0.995		0.255	0.065	0.057	1.076	0.382
	Location	0.008	0.020	0.056	0.682	1.848					
	School type	-0.010	0.010	-0.120	0.322	1.448					
	Number of classes	0.001	0.002	0.107	0.552	3.192					
	Year	0.000	0.004	0.013	0.911	1.338					
	Total area	-0.001	0.000	-0.006	0.969	2.472					
	Project duration	-0.001	0.000	-0.309	0.019*	1.658					
2g	Constant	-43.870	11.944	-	0.000		0.508	0.272	0.193	4.577	0.000*
	Location	0.006	0.018	0.041	0.739	1.849					
	School type	-0.006	0.009	-0.069	0.525	1.461					
	Number of classes	0.000	0.002	0.038	0.813	3.217					
	Year	0.022	0.006	0.592	0.000	3.069					
	Total area	0.000	0.000	0.038	0.787	2.477					
	Project duration	0.000	0.000	0.205	0.084	1.713					
	Unit cost	0.000	0.000	0.764	0.000*	3.022					

*The related new factor added to the model has a significant impact on the dependent variable
Note: Sig. = Significance; ΔR^2 = R^2 change; B = unstandardized coefficient; β= beta coefficient F = F-test value; SE = standard error; VIF = variance inflation factor.

Table 6. Regression model for project characteristics and managerial complexity.

Model	Project characteristics	B	SE	β	Sig.	VIF	R	R^2	ΔR^2	ANOVA F	ANOVA Sig.
3a	Constant	2.979	0.138	-	0.000		0.337	0.114	0.114	12.556	0.001*
	Location	0.283	0.080	0.337	0.001*	1.000					
3b	Constant	3.389	0.178	-	0.000		0.456	0.208	0.094	12.709	0.000*
	Location	0.270	0.076	0.322	0.001	1.002					
	School type	-0.149	0.044	-0.307	0.001*	1.002					
3c	Constant	3.200	0.170	-	0.000		0.581	0.338	0.130	16.322	0.000*
	Location	0.042	0.087	0.049	0.636	1.573					
	School type	-0.055	0.046	-0.113	0.235	1.293					
	Number of classes	0.028	0.007	0.497	0.000*	1.900					
3d	Constant	23.780	40.097	-	0.555		0.583	0.340	0.002	12.214	0.000*
	Location	0.060	0.095	0.071	0.530	1.841					
	School type	-0.057	0.046	-0.117	0.222	1.302					
	Number of classes	0.027	0.007	0.474	0.000	2.204					
	Year	-0.010	0.020	-0.047	0.609	1.213					
3e	Constant	27.126	40.097	-	0.505		0.586	0.343	0.003	9.817	0.000*
	Location	0.065	0.095	0.077	0.498	1.841					
	School type	-0.065	0.048	-0.133	0.178	1.381					
	Number of classes	0.030	0.008	0.529	0.001	3.082					
	Year	-0.012	0.020	-0.055	0.556	1.230					
	Total area	-0.001	0.000	-0.090	0.484	2.368					
3f	Constant	49.314	41.619	-	0.239		0.606	0.367	0.024	9.006	0.000*
	Location	0.054	0.094	0.064	0.568	1.848					
	School type	-0.045	0.048	-0.093	0.351	1.448					
	Number of classes	0.027	0.008	0.477	0.002	3.192					
	Year	-0.023	0.021	-0.106	0.269	1.338					
	Total area	-0.001	0.000	-0.141	0.281	2.472					
	Project duration	0.001	0.000	0.201	0.046*	1.658					
3g	Constant	137.334	62.117	-	0.030		0.625	0.391	0.024	8.439	0.000*
	Location	0.058	0.093	0.070	0.531	1.849					
	School type	-0.054	0.048	-0.111	0.263	1.461					
	Number of classes	0.029	0.008	0.050	0.001	3.217					
	Year	-0.067	0.031	-0.308	0.033	3.069					
	Total area	-0.001	0.000	-0.129	0.315	2.477					
	Project duration	0.000	0.000	0.165	0.124	1.713					
	Unit cost	0.000	0.000	0.267	0.063	3.022					

*The related new factor added to the model has a significant impact on the dependent variable
Note: Sig. = Significance; ΔR^2 = R^2 change; B = unstandardized coefficient; β= beta coefficient F = F-test value; SE = standard error; VIF = variance inflation factor.

Table 7 Regression model for project characteristics, managerial complexity, and schedule performance index.

Model	Performance indicator	Project characteristics	B	SE	β	Sig.	VIF	R	R^2	ΔR^2	ANOVA	
											F	Sig.
4a/1g	SPI	Constant	56.351	17.169	-	0.001		0.591	0.349	0.349	7.047	0.000*
		Location	-0.038	0.026	-0.168	0.144	1.849					
		School type	0.006	0.013	0.043	0.670	1.461					
		Number of classes	0.003	0.002	0.174	0.253	3.217					
		Year	-0.027	0.009	-0.474	0.002	3.069					
		Total area	-0.001	0.000	-0.162	0.223	2.477					
		Project duration	-0.001	0.000	-0.390	0.001	1.713					
		Unit cost	0.001	0.000	0.369	0.013	3.022					
4b	SPI	Constant	53.004	17.646	-	0.003		0.595	0.354	0.005	6.236	0.000*
		Location	-0.039	0.026	-0.175	0.131	1.857					
		School type	0.007	0.013	0.054	0.603	1.481					
		Number of classes	0.002	0.002	0.128	0.427	3.629					
		Year	-0.026	0.009	-0.446	0.004	3.225					
		Total area	-0.001	0.000	-0.151	0.261	2.505					
		Project duration	-0.001	0.000	-0.405	0.000	1.758					
		Unit cost	0.001	0.000	0.344	0.023	3.138					
		Managerial and organizational complexity	0.024	0.029	0.091	0.400	1.642					

*The related new factor added to the model has a significant impact on the dependent variable
Note: Sig. = Significance; ΔR^2 = R^2 change; B = unstandardized coefficient; β= beta coefficient F = F-test value; SE = standard error; VIF = variance inflation factor.

Table 8 Regression model for project characteristics, managerial complexity, and cost performance index.

Model	Performance indicator	Project characteristics	B	SE	β	Sig.	VIF	R	R^2	ΔR^2	ANOVA	
											F	Sig.
5a/2g	CPI	Constant	-43.870	11.944	-	0.000		0.508	0.258	0.258	4.577	0.000*
		Location	0.006	0.018	0.041	0.739	1.849					
		School type	-0.006	0.009	-0.069	0.525	1.461					
		Number of classes	0.000	0.002	0.038	0.813	3.217					
		Year	0.022	0.006	0.592	0.000	3.069					
		Total area	-0.001	0.000	-0.038	0.787	2.477					
		Project duration	-0.001	0.000	-0.205	0.084	1.713					
		Unit cost	-0.001	0.000	-0.764	0.000	3.022					
5b	CPI	Constant	-44.613	12.319	-	0.000		0.509	0.259	0.001	3.974	0.000*
		Location	0.006	0.018	0.039	0.754	1.857					
		School type	-0.006	0.009	-0.066	0.551	1.481					
		Number of classes	0.000	0.002	0.023	0.896	3.629					
		Year	0.023	0.006	0.601	0.000	3.225					
		Total area	-0.001	0.000	-0.034	0.810	2.505					
		Project duration	0.001	0.000	-0.210	0.082	1.758					
		Unit cost	-0.001	0.000	-0.773	0.000	3.138					
		Managerial and organizational complexity	0.005	0.020	0.031	0.789	1.642					

*The related new factor added to the model has a significant impact on the dependent variable
Note: Sig. = Significance; ΔR^2 = R^2 change; B = unstandardized coefficient; β= beta coefficient F = F-test value; SE = standard error; VIF = variance inflation factor.

5. Discussion

Several studies have focused on the underlying factors that influence project performance in the construction industry. Most of these studies relied on subjective judgments and surveyed construction professionals or engineers. To date, there is no detailed study on which and to what extent project characteristics are reliable factors in predicting construction project performance. In addition, the impact of management complexity/difficulty on project performance has not been studied in detail. Thus, the main purpose of this study is to introduce a predictive model based on project characteristics and organizational and managerial complexity by considering two important and empirical performance metrics, namely SPI and CPI. Based on the results of hierarchical regression model and correlation analysis together, we developed the predictor model for school construction projects delivered by "design-bid-build" contract type (Fig. 3).

According to the model, most project characteristics such as location, school type, project duration, unit cost, and year are significant predictors of school construction schedule performance. Among these factors, particularly long project duration, building schools in urban areas, and working on high school projects negatively affect the schedule performance of school construction. Therefore, these attributes are included as critical predictors in the regression model. Although the long project time is highly emphasized as a critical factor for schedule delays in previous studies (Çevikbaş and Işık, 2021; Gunduz and Elsherbeny, 2020), other factors such as the construction of school projects in urban areas and working on high school projects are new findings of the current study in terms of effective predictors of project performance. The poor time performance in the construction of high schools could be related to the design complexity of these projects due to the requirements of laboratories and other facilities (e.g., conference halls, gymnasiums, and dining halls) (Chan et al., 2004; Egwim et al., 2021). On the other hand, only the unit cost factor is a strong predictor of both cost and time performance in school construction projects. The negative effect of year and unit cost is due to the high inflation rate in Turkey, especially after 2018. The unit cost in building construction in Turkey increases by 45% every year (Turkish Statistical Institute, 2022). Thus, we can conclude that the high inflation rate, especially in developing countries, could have a significant impact on the poor time and cost performance observed in construction.

The results also show that project characteristics such as location, school type, number of classes, and project duration are significant predictors of the managerial and organizational complexity/difficulty of school construction. In particular, schools built in urban areas have to be designed for high capacity, which increases the complexity of the projects. The number of classes and other facilities also increases with this condition. All these factors also stimulate the project duration of school construction. Therefore, we can conclude that there is a snowball effect of project characteristics to each other, leading to management and organizational difficulties for practitioners. This kind of domino effect is also emphasized for quality deficiency-based attributes that cause cost overruns in construction (Kazar et al., 2022). On the other hand, year of construction and unit cost do not have a significant impact on managerial and organizational difficulties in school construction. As mentioned before, unit cost and year are positively correlated with each other due to the high inflation rate in Turkey (Turkish Statistical Institute, 2022).

On the other hand, there is no significant and direct relationship found between project performance (e.g., time and cost) and managerial and organizational difficulties according to both hierarchical regression model and correlation analysis. Nevertheless, we can observe the indirect relationship between schedule performance and managerial and organizational complexity because project characteristics such as location, school type, and project duration have a similar and common impact on them separately. Thus, we can understand that as the project duration increases, construction management becomes more difficult for construction professionals and engineers. In addition, the construction of more complex school projects, such as high schools in urban areas, makes it more difficult to manage the construction process. Overall, the project characteristics of project duration, school type, and location are significant predictors of schedule performance and management difficulties, and only unit cost has a direct and significant impact on school construction cost performance (Fig. 3).

According to the results, attributes such as location, school type and project duration are common and major predictors of time and cost overruns in school construction projects (model 4 and 5). In particular, location (urban vs. rural) and project duration have a significant impact on project performance. The construction of a school in a rural area and long project durations lead to higher risks for the performance of school projects.

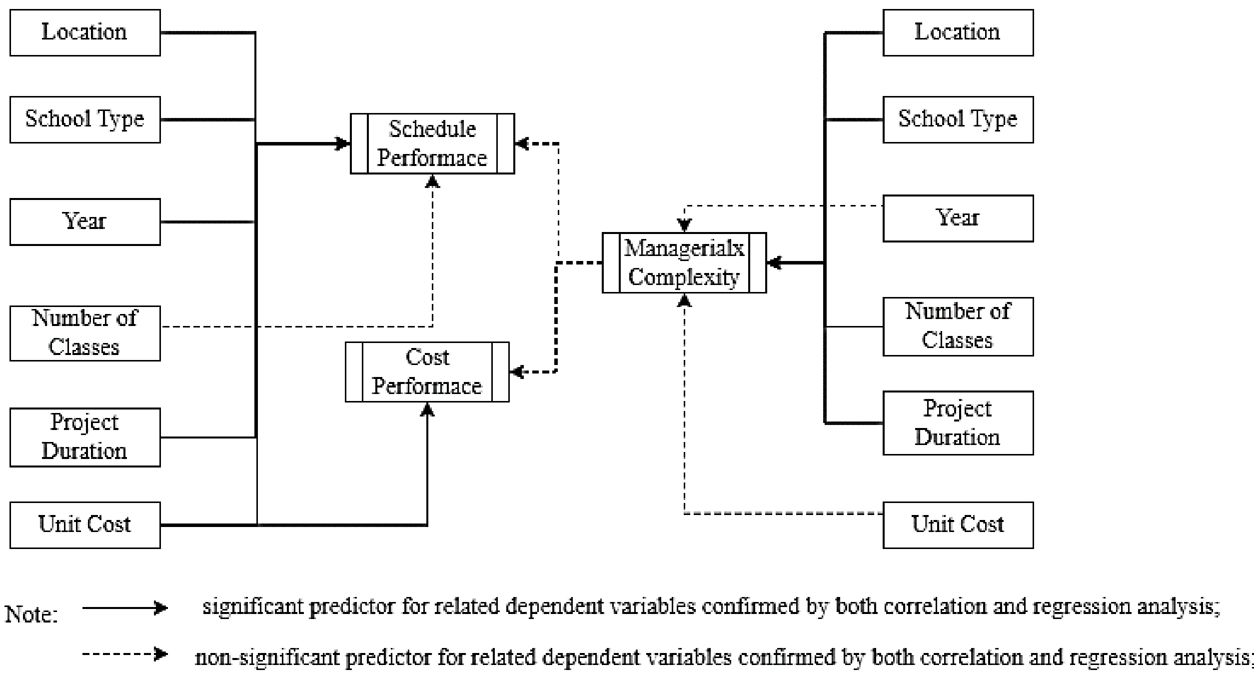

Figure 3. Predictor model for project performance of school constructions.

Design-bid-build is the traditional procurement method for school construction, especially in developing countries. The weaknesses of this type of contract in project performance are well known, and it is essential to make improvements in this type of procurement. Contractors especially for public investments are selected only on the basis of low bid criteria without considering other factors in the "design-bid-build" tendering method in Turkey. However, qualification-based selection (QBS), which focuses on all aspects of contractors such as past performance, technical suitability and resources instead of considering only cost bids, should be integrated into the design-bid-build procurement type. For example, contractors selected on the basis of QBS have been found to be more successful in terms of cost and time performance (Molenaar et al., 2010; Perrenoud et al., 2017).

The current study has some limitations. First, the relevant project information was collected in Turkey, so a similar approach should be adopted in other developing developed countries. Secondly, comparisons should be made between developed and developing countries in terms of performance predictors. New and more empirical performance measures such as quality, satisfaction, and safety scores should be included to obtain more reliable results on the predictors. A similar approach can also be implemented for other procurement types, such as design-build, construction management, and build-operate-transfer, to explore key predictors of project performance. It can also be used to compare contractor performance using empirical performance measures such as SPI and CPI. Mediator analysis can be performed to evaluate the mediating effects of managerial and organizational difficulties on project performance. All these shortcomings can be addressed in detail in future studies.

6. Conclusion

A number of studies have attempted to identify the most critical parameters that influence project performance in the construction industry. Although these attempts have made significant contributions to the body of knowledge, they have mostly relied on subjective assessment through a questionnaire administered to construction stakeholders. On the other hand, focusing on the empirical data of specific construction projects delivered through the traditional approach allows us to explore new and reliable predictors to be used by construction professionals. To systematically visualize these predictors, we perform hierarchical regression and correlation analysis together and present a framework. The conclusion of this paper can be de-scripted as below:

1) The project characteristics such as location, school type, and project duration have a significant impact on project performance and management difficulties in school construction.
2) A snowball effect of project characteristics on managerial and organizational complexity/difficulties is also found in the current study.
3) We also observed the indirect relationship between managerial and organizational difficulties and project schedule performance.

Poor time and cost performance, especially in design-bid-build projects, is still one of the major challenges in construction and no serious solutions have been introduced yet. QBS-based design-bid-build delivery method could provide benefits for construction decision makers and practitioners to improve the performance of construction projects contracted by government institutions. By considering the results, time and cost overruns can be estimated at the design phase. Also, QBS-based procurement system considers all capabilities such as past performance, technical and resource capacity of contractors instead of considering only the lowest bid. Another recommendation is to develop a data management system to monitor and evaluate project performance during the construction process. Such a database could also be used to predict the time, cost and quality performance of future similar constructions. The predictors can also be useful for risk and quality management processes to get the right actions when an unexpected situation occurs. Based on these predictors, an artificial intelligence (AI)-based predictive model can be easily developed. In the future, prediction will be more important to evaluate potential risks and reasons for poor performance in construction, so it is very important to focus on more reliable and accurate predictors during estimation and monitoring processes.

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References

Abou Chakra, H., and Ashi, A. (2019). Comparative analysis of design/build and design/bid/build project delivery systems in Lebanon. *Journal of Industrial Engineering International*, *15*, 147–152. https://doi.org/10.1007/s40092-019-00323-1

Akinwande, M. O., Dikko, H. G., and Samson, A. (2015). Variance Inflation Factor: As a Condition for the Inclusion of Suppressor Variable(s) in Regression Analysis. *Open Journal of Statistics*, *05*(07), 754–767. https://doi.org/10.4236/ojs.2015.57075

Alshihri, S., Al-gahtani, K., and Almohsen, A. (2022). Risk Factors That Lead to Time and Cost Overruns of Building Projects in Saudi Arabia. *Buildings*, *12*(7). https://doi.org/10.3390/buildings12070902

Amoatey, C. T., Ameyaw, Y. A., Adaku, E., and Famiyeh, S. (2015). Analysing delay causes and effects in Ghanaian state housing construction projects. *International Journal of Managing Projects in Business*. https://doi.org/10.1108/IJMPB-04-2014-0035

Baccarini, D. (1999). The Logical Framework Method for Defining Project Success. *Project Management Journal*, *30*(4), 25–32. https://doi.org/10.1177/875697289903000405

Barrientos-Orellana, A., Ballesteros-Pérez, P., Mora-Melia, D., González-Cruz, M. C., and Vanhoucke, M. (2022). Stability and accuracy of deterministic project duration forecasting methods in earned value management. *Engineering, Construction and Architectural Management*, *29*(3), 1449–1469. https://doi.org/10.1108/ECAM-12-2020-1045

Batselier, J., and Vanhoucke, M. (2015). Empirical Evaluation of Earned Value Management Forecasting Accuracy for Time and Cost. *Journal of Construction Engineering and Management*, *141*(11). https://doi.org/10.1061/(asce)co.1943-7862.0001008

Bringula, R. P., Moraga, S. D., Catacutan, A. E., Jamis, M. N., and Mangao, D. F. (2018). Factors influencing online purchase intention of smartphones: A hierarchical regression analysis. *Cogent Business and Management*, *5*(1), 1–18. https://doi.org/10.1080/23311975.2018.1496612

Calahorra-Jimenez, M., Alarcón, L. F., Torres-Machi, C., Chamorro, A., and Molenaar, K. (2020). Improving cost performance in design-bid-build road projects by mapping the reasons for cost overruns into the project phases. *Revista de La Construccion*, *19*(2), 334–345. https://doi.org/10.7764/RDLC.19.2.334

Çevikbaş, M., and Işık, Z. (2021). An overarching review on delay analyses in construction projects. *Buildings*, *11*(3). https://doi.org/10.3390/buildings11030109

Chan, A. P. C., and Chan, A. P. L. (2004). Key performance indicators for measuring construction success. In *Benchmarking* (Vol. 11, Issue 2, pp. 203–221). https://doi.org/10.1108/14635770410532624

Chan, A. P. C., and Chan, A. P. L. (2009). Identifying key performance indicators for use in control of pre-project stage process in construction. *International Journal of Productivity and Performance Management*, *11*(2), 160–173. https://www-emeraldinsight-com.ezproxy.usc.edu.au/doi/pdfplus/10.1108/14635770410532624

Chan, A. P. C., Scott, D., and Chan, A. P. L. (2004). Factors Affecting the Success of a Construction Project. *Journal of Construction Engineering and Management*, *130*(1), 153–155. https://doi.org/10.1061/(asce)0733-9364(2004)130:1(153)

Chileshe, N., and Berko, P. D. (2010). Causes of project cost overruns within the Ghanaian road construction sector. *Proceedings 5th Built Environment Conference*, *July*, 67–80.

Cho, K. M., Hong, T. H., and Hyun, C. T. (2009). Effect of project characteristics on project performance in construction projects based on structural equation model. *Expert Systems with Applications*, *36*(7), 10461–10470. https://doi.org/10.1016/j.eswa.2009.01.032

Czemplik, A. (2014). Application of earned value method to progress control of construction projects. *Procedia Engineering*, *91*, 424–428. https://doi.org/10.1016/j.proeng.2014.12.087

Demirkesen, S., and Ozorhon, B. (2017). Measuring project management performance: Case of construction industry. Engineering Management Journal, 29(4), 258-277, https://doi.org/10.1080/10429247.2017.1380579.

Durdyev, S. (2020). Review of construction journals on causes of project cost overruns. *Engineering, Construction and Architectural Management*, *28*(4), 1241–1260. https://doi.org/10.1108/ECAM-02-2020-0137

Egwim, C. N., Alaka, H., Toriola-Coker, L. O., Balogun, H., Ajayi, S., and Oseghale, R. (2021). Extraction of underlying factors causing construction projects delay in Nigeria. *Journal of Engineering, Design and Technology*. https://doi.org/10.1108/JEDT-04-2021-0211

Franceschini, F., Galetto, M., and Turina, E. (2009). Service quality monitoring by performance indicators: A proposal for a structured methodology. *International Journal of Services and Operations Management*, *5*(2), 251–273. https://doi.org/10.1504/IJSOM.2009.023235

Gunduz, M., and Elsherbeny, H. A. (2020). Operational Framework for Managing Construction-Contract Administration Practitioners' Perspective through Modified Delphi Method. *Journal of Construction Engineering and Management*. https://doi.org/10.1061/(asce)co.1943-7862.0001768

Gunduz, M., and Tehemar, S. R. (2020). Assessment of delay factors in construction of sport facilities through multi criteria decision making. *Production Planning and Control*, *31*(15), 1291–1302. https://doi.org/10.1080/09537287.2019.1704903

Hampson, K. D., Kraatz, J. A., and Sanchez, A. X. (2014). The global construction industry and RandD. In *R and D Investment and Impact in the Global Construction Industry*. https://doi.org/10.4324/9781315774916

Haponava, T., and Al-Jibouri, S. (2012). Proposed System for Measuring Project Performance Using Process-Based Key Performance Indicators. *Journal of Management in Engineering*, *28*(2), 140–149. https://doi.org/10.1061/(asce)me.1943-5479.0000078

Hashem M. Mehany, M. S., Bashettiyavar, G., Esmaeili, B., and Gad, G. (2018). Claims and Project Performance between Traditional and Alternative Project Delivery Methods. *Journal of Legal Affairs and Dispute Resolution in Engineering and Construction*, *10*(3). https://doi.org/10.1061/(asce)la.1943-4170.0000266

Haynes, N. S., and Love, P. E. D. (2004). Psychological adjustment and coping among construction project managers. *Construction Management and Economics*. https://doi.org/10.1080/0144619042000201330

Heravi, G., and Ilbeigi, M. (2012). Development of a comprehensive model for construction project success evaluation by contractors. *Engineering, Construction and Architectural Management*, *19*(5), 526–542. https://doi.org/10.1108/09699981211259603

Johnson, R. M., and Babu, R. I. I. (2020). Time and cost overruns in the UAE construction industry: a critical analysis. *International Journal of Construction Management*. https://doi.org/10.1080/15623599.2018.1484864

Kaming, P. F., Olomolaiye, P. O., Holt, G. D., and Harris, F. C. (1997). Factors influencing construction time and cost overruns on high-rise projects in Indonesia. *Construction Management and Economics*, *15*(1), 83–94. https://doi.org/10.1080/014461997373132

Kavuma, A., Ock, J., and Jang, H. (2019). Factors influencing Time and Cost Overruns on Freeform Construction Projects. *KSCE Journal of Civil Engineering*, *23*(4), 1442–1450. https://doi.org/10.1007/s12205-019-0447-x

Kazar, G., Doğan, N. B., Ayhan, B. U., and Tokdemir, O. B. (2022). Quality Failures–Based Critical Cost Impact Factors: Logistic Regression Analysis. In *Journal of Construction Engineering and Management* (Vol. 148, Issue 12). https://doi.org/10.1061/(asce)co.1943-7862.0002412

Kerzner, H. (2014). Project Management Best Practices: Achieving Global Excellence. In *Project Management Best Practices: Achieving Global Excellence* (Vol. 9781118657). https://doi.org/10.1002/9781118835531

Kim, B.-C., and Reinschmidt, K. F. (2010). Probabilistic Forecasting of Project Duration Using Kalman Filter and the Earned Value Method. *Journal of Construction Engineering and Management*, *136*(8), 834–843. https://doi.org/10.1061/(asce)co.1943-7862.0000192

Leon, H., Osman, H., Georgy, M., and Elsaid, M. (2018). System Dynamics Approach for Forecasting Performance of Construction Projects. *Journal of Management in Engineering*, *34*(1). https://doi.org/10.1061/(asce)me.1943-5479.0000575

Leung, M., Liang, Q., and Chan, I. Y. S. (2017). Development of a Stressors–Stress–Performance–Outcome Model for Expatriate Construction Professionals. *Journal of Construction Engineering and Management*. https://doi.org/10.1061/(asce)co.1943-7862.0001266

Ma, L., and Fu, H. (2020). Exploring the influence of project complexity on the mega construction project success: a qualitative comparative analysis (QCA) method. *Engineering, Construction and Architectural Management*, *27*(9), 2429–2449. https://doi.org/10.1108/ECAM-12-2019-0679

Marzouk, M. M., and Gaid, E. F. (2018). Assessing Egyptian construction projects performance using principal component analysis. *International Journal of Productivity and Performance Management*, *67*(9), 1727–1744. https://doi.org/10.1108/IJPPM-06-2017-0134

McKinsey Global Institute. (2017). Reinventing Construction: A Route To Higher Productivity. In *Mckinsey Global Insititute* (Issue February). http://www.mckinsey.com/industries/capital-projects-and-infrastructure/our-insights/reinventing-construction-through-a-productivity-revolution

Mellado, F., Lou, E. C. W., and Becerra, C. L. C. (2020). Synthesising performance in the construction industry: An analysis of performance indicators to promote project improvement. *Engineering, Construction and Architectural Management*, *27*(2), 579–608. https://doi.org/10.1108/ECAM-09-2018-0419

Meng, X. (2012). The effect of relationship management on project performance in construction. *International Journal of Project Management*, *30*(2), 188–

198. https://doi.org/10.1016/j.ijproman.2011.04.002

Minchin, R. E., Li, X., Issa, R. R., and Vargas, G. G. (2013). Comparison of Cost and Time Performance of Design-Build and Design-Bid-Build Delivery Systems in Florida. *Journal of Construction Engineering and Management*, *139*(10). https://doi.org/10.1061/(asce)co.1943-7862.0000746

Molenaar, K. R., Sobin, N., and Antillón, E. I. (2010). A synthesis of best-value procurement practices for sustainable design-build projects in the public sector. *Journal of Green Building*, *5*(4), 148–157. https://doi.org/10.3992/jgb.5.4.148

Montalbán-Domingo, L., García-Segura, T., Amalia Sanz, M., and Pellicer, E. (2019). Social Sustainability in Delivery and Procurement of Public Construction Contracts. *Journal of Management in Engineering*, *35*(2). https://doi.org/10.1061/(asce)me.1943-5479.0000674

Moon, H., Kim, K., Lee, H.-S., Park, M., Williams, T. P., Son, B., and Chun, J.-Y. (2020). Cost Performance Comparison of Design-Build and Design-Bid-Build for Building and Civil Projects Using Mediation Analysis. *Journal of Construction Engineering and Management*, *146*(9). https://doi.org/10.1061/(asce)co.1943-7862.0001873

Moradi, S., Ansari, R., and Taherkhani, R. (2022). A Systematic Analysis of Construction Performance Management: Key Performance Indicators from 2000 to 2020. *Iranian Journal of Science and Technology - Transactions of Civil Engineering*, *46*(1), 15–31. https://doi.org/10.1007/s40996-021-00626-7

Mpofu, B., Ochieng, E. G., Moobela, C., and Pretorius, A. (2017). Profiling causative factors leading to construction project delays in the United Arab Emirates. *Engineering, Construction and Architectural Management*. https://doi.org/10.1108/ECAM-05-2015-0072

Mulla, S. S., and Waghmare, A. P. (2015). A Study of Factors Caused for Time and Cost Overruns in Construction Project and their Remedial Measures. *Journal of Engineering Research and Applications Www.Ijera.Com ISSN*, *5*(16), 2248–962248. www.ijera.com

Nassar, N., and AbouRizk, S. (2014). Practical Application for Integrated Performance Measurement of Construction Projects. *Journal of Management in Engineering*, *30*(6). https://doi.org/10.1061/(asce)me.1943-5479.0000287

Nguyen, P. H. D., Lines, B. C., and Tran, D. Q. (2018). Best-Value Procurement in Design-Bid-Build Construction Projects: Empirical Analysis of Selection Outcomes. *Journal of Construction Engineering and Management*, *144*(10). https://doi.org/10.1061/(asce)co.1943-7862.0001550

Orihuela, P., Pacheco, S., and Orihuela, J. (2017). Proposal of Performance Indicators for the Design of Housing Projects. *Procedia Engineering*, *196*, 498–505. https://doi.org/10.1016/j.proeng.2017.07.230

Perrenoud, A., Lines, B. C., Savicky, J., and Sullivan, K. T. (2017). Using Best-Value Procurement to Measure the Impact of Initial Risk-Management Capability on Qualitative Construction Performance. *Journal of Management in Engineering*, *33*(5). https://doi.org/10.1061/(asce)me.1943-5479.0000535

PMI. (2005). Practice Standard for Earned Value Management. *PM, March-April*, 135. http://marketplace.pmi.org/Pages/ProductDetail.aspx?GMProduct=00101262001%5Cnhttp://procurement.citsolutions.edu.au/Clients/DOGPM/documentation/Earned_Value.pdf%5Cnhttp://scholar.google.com/scholar?hl=enandbtnG=Searchandq=intitle:Practice+Standard+for+Earned+

Proaño-Narváez, M., Flores-Vázquez, C., Vásquez Quiroz, P., and Avila-Calle, M. (2022). Earned Value Method (EVM) for Construction Projects: Current Application and Future Projections. *Buildings*, *12*(3). https://doi.org/10.3390/buildings12030301

Radmacher, S. A., and Martin, D. J. (2001). Identifying significant predictors of student evaluations of faculty through hierarchical regression analysis. *Journal of Psychology: Interdisciplinary and Applied*, *135*(3), 259–268. https://doi.org/10.1080/00223980109603696

Radujković, M., Vukomanović, M., and Burcar Dunović, I. (2010). Application of Key Performance Indicators in South-Eastern European construction. *Journal of Civil Engineering and Management*, *16*(4), 521–530. https://doi.org/10.3846/jcem.2010.58

Reddy, M. V. (2019). Correlation Analysis and Regression Analysis. In *Statistical Methods in Psychiatry Research and SPSS* (pp. 163–176). https://doi.org/10.1201/9780429023309-12

Shrestha, P. P., and Fernane, J. D. (2017). Performance of Design-Build and Design-Bid-Build Projects for Public Universities. *Journal of Construction Engineering and Management*, *143*(3). https://doi.org/10.1061/(asce)co.1943-7862.0001241

Skibniewski, M. J., and Ghosh, S. (2009). Determination of Key Performance Indicators with Enterprise Resource Planning Systems in Engineering Construction Firms. *Journal of Construction Engineering and Management*, *135*(10), 965–978. https://doi.org/10.1061/(asce)0733-9364(2009)135:10(965)

Su, G., and Khallaf, R. (2022). Research on the Influence of Risk on Construction Project Performance: A Systematic Review. *Sustainability (Switzerland)*, *14*(11). https://doi.org/10.3390/su14116412

Tripathi, K. K., and Jha, K. N. (2018). An Empirical Study on Performance Measurement Factors for Construction Organizations. *KSCE Journal of Civil Engineering*, *22*(4), 1052–1066. https://doi.org/10.1007/s12205-017-1892-z

Turkish Statistical Institute. (2022). *Constuction Cost Index*. https://data.tuik.gov.tr/Search/Search?text=inşaat maliyet endeksianddil=1

Vatcheva, K., and Lee, M. (2016). Multicollinearity in Regression Analyses Conducted in Epidemiologic Studies. *Epidemiology: Open Access*, *06*(02). https://doi.org/10.4172/2161-1165.1000227

Wells, H. (2012). How effective are project management methodologies? An explorative evaluation of their benefits in practice. *Project Management Journal*, *43*(6), 43–58. https://doi.org/10.1002/pmj.21302

Xiao, H., and Proverbs, D. (2003). Factors influencing contractor performance: An international investigation. *Engineering, Construction and Architectural Management*, *10*(5), 322–332. https://doi.org/10.1108/09699980310502937

Yehiel, R. (2013). Root-Cause Analysis of Construction-Cost Overruns. *Journal of Construction Engineering and Management*.

Yu, T., Shen, G. Q., and Shi, Q. (2017). Comparing the Performance Quality of Design-Bid-Build and Design-Build Delivery Methods. *Journal of Construction Engineering and Management*, *143*(4). https://doi.org/10.1061/(asce)co.1943-7862.0001262

Yuan, J., Zeng, A. Y., Skibniewski, M. J., and Li, Q. (2009). Selection of performance objectives and key performance indicators in public-private partnership projects to achieve value for money. *Construction Management and Economics*, *27*(3), 253–270. https://doi.org/10.1080/01446190902748705

Zahoor, H., Khan, R. M., Nawaz, A., Ayaz, M., and Maqsoom, A. (2022). Project control and forecast assessment of building projects in Pakistan using earned value management. *Engineering, Construction and Architectural Management*, *29*(2), 842–869. https://doi.org/10.1108/ECAM-11-2020-0989